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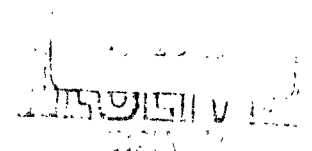
APPLICATION AND EVALUATION
OF A
DIGITAL COMPUTER PROGRAM
FOR
INTERIOR BALLISTICS

STUART LEVY
FORREST McMAINS

AMCMS 5023.11.18400

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JANUARY 1964



PICATINNY ARSENAL
DOVER, NEW JERSEY

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BY

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Also appreciated is the cooperation of Sidney Bernstein and Robert Garufi of the Artillery Ammunition Laboratory, Ammunition Engineering Directorate, who supplied some of the firing data used in this report.

SECTION I

INTRODUCTION

The object of this study is to compare simulated firing results -- obtained from a digital computer program -- with actual firing data. "The Digital Computer Program for Interior Ballistics" by Sidney Kravitz (Reference 1) was used, and this program was restricted to Problem 2 and 3.

In Problem 1, burning rate divided by web (B/W) and charge weight are given and the computer will calculate maximum pressure and muzzle velocity.

In Problem 2, maximum pressure and charge are given and the computer will calculate muzzle velocity and B/W .

In Problem 3, maximum pressure and muzzle velocity are given and the computer will calculate charge and B/W .

A study of Problem 1 was omitted from this report because its solution depends on a B value which is not part of the firing data. A study is under preparation which will endeavor to calculate these B values and use them in Problem 1.

In Section II, simulated and actual firing data are tabulated for eight weapon systems. Also listed are percentage errors and the burning rate factor B for Problem 2 for various pressure ranges and propellants.

A discussion of the results is given in Section III.

SECTION II

FIRING DATA STUDY OF EIGHT WEAPON SYSTEMS

1. 75MM HOWITZER, M3, M1A1

Gun Constants

Projectile Weight ----- 13.1 lbs.
 Chamber Volume ----- 59.0 in.³
 Propellant Type ----- M2 (S.P.)
 Total Travel ----- 39.3 in.

Problem 2

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Charge Weight (lbs)	Firing Velocity (ft/sec)	Simulated Velocity (ft/sec)	Burning Rate Factor B
2,000	0.0148	24,100	0.4125	1,000	980.9	0.00436
					0.19	

Problem 3

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Velocity (ft/sec)	Firing Charge Weight (lbs)	Simulated Charge Weight (lbs)	Burning Rate Factor B
2,000	0.0148	24,100	1,000	0.4125	0.431	0.00407
					4.48	

2. 75MM GUN, M1, M1A2

Gun Constants

Projectile Weight ----- 9.3 lbs.
 Chamber Volume ----- 200 in.³
 Propellant Type ----- M2 (M.P.)
 Total Travel ----- 156 in.

Problem 2

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Charge Weight (lbs.)	Firing Velocity (ft/sec)	Simulated Velocity (ft/sec)	% Error	Burning Rate Factor B
2,000	0.0598	46,900	3.86	3,400	3,475	2.2	0.0039

Problem 3

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Velocity (ft/sec)	Firing Charge Weight (lbs)	Simulated Charge Weight (lbs)	% Error	Burning Rate Factor B
2,000	0.0598	46,900	3,400	3.86	3.647	5.51	0.00417

3. 90MM GUN, M41

Gun Constants

Projectile Weight ----- 12.65 lbs.
 Chamber Volume ----- 300 in.³
 Propellant Type ----- M17 (M.P.)
 Total Travel ----- 155 in.

Problem 2

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Charge Weight (lbs.)	Firing Velocity (ft/sec)	Simulated Velocity (ft/sec)	% Error	Burning Rate Factor B
2,000	0.052	50,500	8.58	4,000	3,946	1.35	0.0103

Problem 3

DID NOT RUN

5. 105MM GUN, M68

Gun Constants

Projectile Weight ----- 12.8 lbs,
 Chamber Volume ----- 384 in.³
 Propellant Type ----- T36 (M.P.)
 Total Travel ----- 178 in.

Problem 2

Starting Pressure (psi) -----	2,000	Web (in.) -----	0.046	Maximum Pressure (psi) -----	58,500	Charge Weight (lbs) -----	12.09	Firing Velocity (ft/sec) -----	4,850	Simulated Velocity (ft/sec) -----	4,768	% Error -----	1.69	Burning Rate Factor B -----	0.00829
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Problem 3

DID NOT RUN

6. 155MM HOWITZER, M1

A. Single Perforated

Gun Constants

Projectile Weight ----- 95 lbs.
 Chamber Volume ----- 795 in.³
 Propellant Type ----- M1 (S.P.)
 Total Travel ----- 115.5 in.

Problem 2

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Charge Weight (lbs)	Firing Velocity (ft/sec)	Simulated Velocity (ft/sec)	% Error	Burning Rate Factor B
2,000	0.0165	5,520	1.95	680	694	2.05	0.00413
2,000	0.0165	7,130	2.444	770	775	0.65	0.00421
2,000	0.0165	9,666	3.0875	880	879	0.11	0.00439
2,000	0.0165	13,800	3.981	1,020	1,008	0.01	0.00465
2,000	0.0165	21,735	5.500	1,220	1,200	1.64	0.00495

Problem 3

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Velocity (ft/sec)	Firing Charge Weight (lbs)	Simulated Charge Weight (lbs.)	% Error	Burning Rate Factor B
2,000	0.0165	5,520	680	1.95	1.854	4.92	0.00437
2,000	0.0165	9,666	880	3.0875	3.085	0.08	0.00440

CONTINUED

6. 155MM HOWITZER, M1 (Continued)

B. Multi-perforated

Gun Constants

Projectile Weight ----- 95 lbs.
 Chamber Volume ----- 795 in.³
 Propellant Type ----- M1 (M.P.)
 Total Travel ----- 115.5 in.

Problem 2

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Charge Weight (lbs)	Firing Velocity (ft/sec)	Simulated Velocity (ft/sec)	% Error	Burning Rate Factor B
2,000	0.0334	6,000	4.156	880	890	1.13	0.00300
2,000	0.0334	8,050	5.319	1,020	1,024	0.39	0.00324
2,000	0.0334	11,730	7.500	1,220	1,229	0.74	0.00312
2,000	0.0334	20,125	9.810	1,520	1,497	1.51	0.00349
2,000	0.0334	35,650	13.188	1,850	1,820	1.62	0.00369

Problem 3

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Velocity (ft/sec)	Firing Charge Weight (lbs.)	Simulated Charge Weight (lbs.)	% Error	Burning Rate Factor B
2,000	0.0334	6,000	880	4.156	3.819	8.11	0.00340
2,000	0.0334	11,730	1,220	7.500	7.179	4.28	0.00326

7. 175MM GUN, M113

Gun Constants

Projectile Weight ----- 147.75 lbs.
 Chamber Volume ----- 2,898 in.³
 Propellant Type ----- M6 (M.P.)
 Total Travel ----- 352 in.

Problem 2

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Charge Weight (lbs.)	Firing Velocity (ft/sec)	Simulated Velocity (ft/sec)	% Error	Burning Rate Factor B
2,000	0.069	13,000	20.58	1,675	1,788	6.75	0.0052
2,000	0.069	21,700	37.75	2,310	2,373	2.73	0.00449
2,000	0.069	50,100	55.56	3,000	3,070	2.33	0.00498

Problem 3

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Velocity (ft/sec)	Firing Charge Weight (lbs.)	Simulated Charge Weight (lbs.)	% Error	Burning Rate Factor B
2,000	0.069	13,000	1,675	20.58	17.234	16.26	0.00678
2,000	0.069	50,100	3,000	55.56	52.513	4.94	0.00534

8. 8-INCH HOWITZER, M2

A. Single Perforated

Gun Constants

Projectile Weight ----- 200 lbs.
 Chamber Volume ----- 1,485 in.³
 Propellant Type ----- M1 (S.P.)
 Total Travel ----- 164 in.

Problem 2

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Charge Weight (lbs.)	Firing Velocity (ft/sec)	Simulated Velocity (ft/sec)	% Error	Burning Rate Factor B
2,000	0.0161	9,300	5.33	820	836	1.95	0.00396
2,000	0.0161	11,600	6.28	900	916	1.78	0.00413
2,000	0.0161	14,800	7.52	1,000	1,005	0.50	0.00427
2,000	0.0161	20,000	9.54	1,150	1,140	0.87	0.00428
2,000	0.0161	31,800	13.16	1,380	1,360	1.45	0.00448

Problem 3

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Velocity (ft/sec)	Firing Charge Weight (lbs.)	Simulated Charge Weight (lbs.)	% Error	Burning Rate Factor B
2,000	0.0161	9,300	820	5.33	5.043	5.38	0.00430
2,000	0.0161	11,600	900	6.28	6.036	3.89	0.00439
2,000	0.0161	14,800	1,000	7.52	7.394	1.68	0.00439
2,000	0.0161	20,000	1,150	9.54	9.686	1.53	0.00416
2,000	0.0161	31,800	1,380	13.16	13.57	3.11	0.00419

(CONTINUED)

8. 8-INCH HOWITZER, M2 (Continued)

B. Multi-perforated

Gun Constants

Projectile Weight ----- 200 lbs.
 Chamber Volume ----- 1,485 in.³
 Propellant Type ----- M1 (M.P.)
 Total Travel ----- 164 in.

Problem 2

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Charge Weight (lbs.)	Firing Velocity (ft/sec)	Simulated Velocity (ft/sec)	% Error	Burning Rate Factor B
2,000	0.0414	15,400	16.63	1,380	1,384	0.29	0.00345
2,000	0.0414	23,200	21.84	1,640	1,628	0.73	0.00357
2,000	0.0414	37,500	28.05	1,950	1,917	1.69	0.00358

Problem 3

Starting Pressure (psi)	Web (in.)	Maximum Pressure (psi)	Velocity (ft/sec)	Firing Charge Weight (lbs.)	Simulated Charge Weight (lbs.)	% Error	Burning Rate Factor B
2,000	0.0414	15,400	1,380	16.63	16.36	1.62	0.00353
2,000	0.0414	23,200	1,640	21.84	22.16	1.47	0.00343
2,000	0.0414	37,500	1,950	28.05	29.20	4.10	0.00343

SECTION III

DISCUSSION OF RESULTS

Most of the velocity variations for Problem 2 $\frac{V_{\text{firing}} - V_{\text{simulated}}}{V_{\text{firing}}} \times 100$ were about 2% or less.

In Problem 3, the charge variations $\frac{C_{\text{firing}} - C_{\text{simulated}}}{C_{\text{firing}}} \times 100$ ranged from 0.8% to 16.25%.

In some instances, although an answer was obtained from Problem 2, the same data in Problem 3 gave no solution. This occurred in the M68 105mm Gun and the M41 90mm Gun. Problem 2 seems to be the most reliable of the two types of problems and B values for Type 2 problems were calculated for all weapon systems.

B is defined as the burning constant, dependent on the chemical properties of the propellant. In the equation of the assumed rate of burning, R is the rate of burning, B is the burning constant, P the pressure of the gas surrounding the burning grains and n an exponent near unity. This equation is given by $R = BP^n$.

Generally an experimental B is determined from closed bomb firings, in which the volume is constant. This B usually differs from experimental Bs from field tests in which the volume is constantly changing as the propellant burns.

The assumptions upon which the ballistic calculations are based do not accurately account for energy losses and inefficiencies in the actual ballistic systems. Therefore, when calculations are made from actual ballistic firings the effect of these factors are accumulated in the B; and it is found that for a given propellant, B varies with the weapon system, the ammunition and pressure level with which it is fired. Appendix A, "B versus Pressure," illustrates this dependency. If B were independent of pressure, the graph of the 8-Inch or 155mm Howitzer would be a vertical line of constant B for varying pressure. Instead it is parabolic in shape. If B were independent of the weapon system, the graphs of the 8-Inch and 155mm Howitzer would coincide. This is to be expected since the propellants used in both systems were of identical chemical composition and granulation. However, they do not coincide -- the B value for the 8-Inch Howitzer is always less than the 155mm Howitzer.

Typical values of B are tabulated in Appendix B. These values were calculated from actual test data, and will be useful for predicting a rough estimate of web size from the output of Type 2 problems. In selecting a B value from the list in Appendix B for a given propellant, use the value of B closest to the weapon system and pressure level. It is expected that as more data is gained from different weapon systems, propellant compositions and pressure levels, the table of Bs will be expanded.

SECTION IV

CONCLUSIONS

The Digital Computer Program for Interior Ballistics was found most useful in doing Case 2 problems where maximum operating pressure and charge are given and velocity is to be calculated. Reliability in reproducing field data is good -- within 2% in most cases.

This program will be valuable in estimating charges and velocities for new weapon systems. Web size for propellant granulation may be estimated, also using the B values in Appendix B. Other B values for different propellants and weapon systems not given in the table may be easily calculated with this program and sufficient field data.

Each calculation requires two IBM Data Cards and about two minutes of machine time. Thus, many hours of laborious written calculations may be eliminated and many solutions obtained in a materially shorter time.

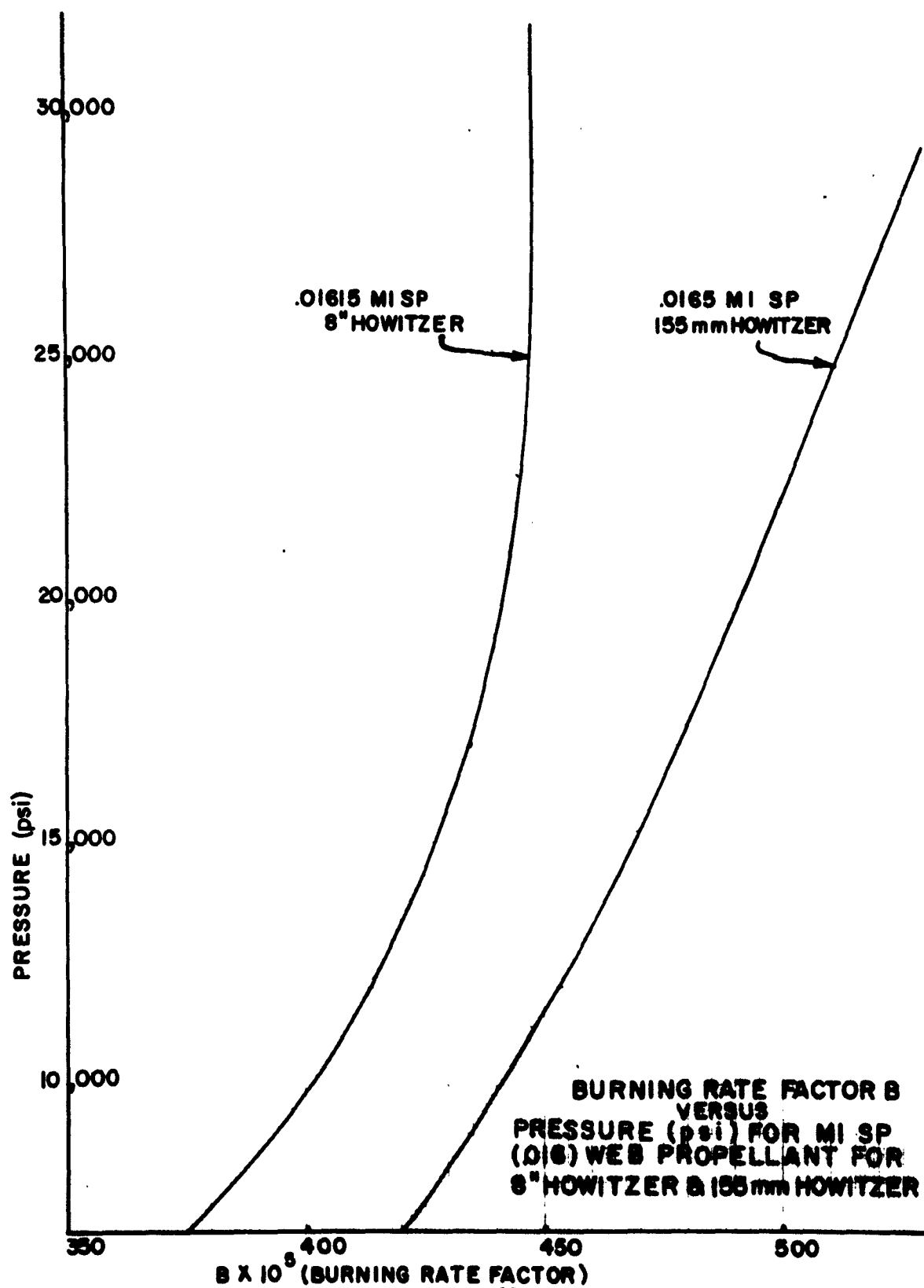
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2. A. O. Edwards and C. R. Grandee, Simulation of the 155mm Howitzer, with Standard Charges, Engineering Sciences Laboratory Information Report, Picatinny Arsenal, October 1962.
3. H. B. Anderson, Master Standard Propellant Calibration Chart for Artillery Ammunition, D&PS Report 825, January 1963.

APPENDICES

APPENDIX A

CHART



APPENDIX B

TABLE

TYPICAL VALUES OF B
(Burning Rate Factor)

<u>Weapon</u>	<u>Pressure (psi)</u>	<u>Propellant</u>	<u>B</u>
75mm Howitzer	25,000	M2 SP	0.00436
76mm Gun	50,000	M2 MP	0.0039
90mm Gun	50,000	M17 MP	0.0103
105mm Howitzer	6,500	T36E1 SP	0.0144
105mm Gun	60,000	T36 MP	0.00829
155mm Howitzer	10,000	M1 SP	0.00440
155mm Howitzer	20,000	M1 MP	0.00350
175mm Gun	20,000	M6 MP	0.00450
175mm Gun	50,000	M6 MP	0.00500
8-Inch Howitzer	15,000	M1 SP	0.00430

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- III. Interior ballistics computer
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